Date: 20th September 2021
Our Ref No.: TJ/UT1/OUT-08

To,
Doosan Heavy Industries & Construction Co., Ltd.
Mr. Youngsoo Son– Project Manager
465 Gangnam-daero, Seocho-gu, Seoul, Korea (06611)

Contract Reference: Engineering, Procurement and Construction Contract between Nepal Water And Energy Development Company Private Limited (NWEDC) and Doosan Heavy Industries & Construction Co. Ltd for the Engineering, Procurement and Construction (EPC) for the 216 MW Hydropower Plant at Upper Trishuli -1, Nepal

Subject: Submission of Review Note on Excavation and Initial Support Drawings of Investigation Tunnel for Powerhouse

References:

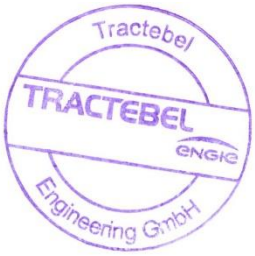
1. Document No. UT1-C-385-CVL-DC-65001 dated 19th August 2021
2. Drawing No.: UT1-C-385-CVL-DG-65001 dated 1st September 2021
3. Drawing No.: UT1-C-385-CVL-DG-65002 dated 1st September 2021

Dear Sir,

Reference is made to the above No.1, 2 and 3 received with transmittal No. UT1-HEP-DHI-D-0038 dated 1st September 2021, regarding excavation and initial support drawings of investigation tunnel for powerhouse.

Please find our comments in the Review Notes (RN-0009, RN-0010, and RN-0011) enclosed herewith this letter.

Sincerely,



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Mr. Carsten GUNTERMANN
Project Manager (CRE)

Enclosure:
1. Review Notes (RN-0009, RN-0010, and RN-0011)

UPPER TRISHULI-1 HEP (216MW)

Client	**Nepal Water and Energy Development Company Private Limited**
Owner's Engineer	**Tractebel Engineering GmbH / Jade Consult**

REVIEW NOTE

Contractor	**Doosan Heavy Industries & Construction Co., Ltd.**		
Title of the Document	Excavation and Initial Support Drawings of Investigation Tunnel for Powerhouse		
Document No.	UT1-C-385-CVL-DG-65002-01 UT1-C-385-CVL-DG-65002-02	Revision	A
Date of Documents	01.09.2021	Received Date	01.09.2021
Transmittal Form No.	UT1-HEP-DHI-D-0038		
Previous Review Date/Status	N/A	Prev. Review Note No.	N/A
Review Note No.	**RN-0011**	**Present Review Date**	**20.09.2021**
		Present Review Status	**RR**

A: Approved AC: Approved with Comments RR: Returned for Resubmission

General Comments

During the online conference on 31. August 2021 on the Adit No. 3 several technical items were discussed and agreed. Some of these issues apply also to the Investigation Tunnel and are not repeated in this review.

For clarification it is noted that for practical reasons, blasted tunnels in rock have always an unavoidable "saw-tooth" profile of the excavation, independent of rock class (see photograph below). The reason is that the drilling tools (pusher-leg or jumbo) cannot drill parallel to the tunnel perimeter due to the restricted space at the perimeter of the already excavated tunnel. This is, however, not explicitly shown on construction drawings, but an overbreak-line (or pay-line) is defined. The saw-tooth profile needs particularly be considered when designing spiling with dowels or pipes in bad rock (Class V).

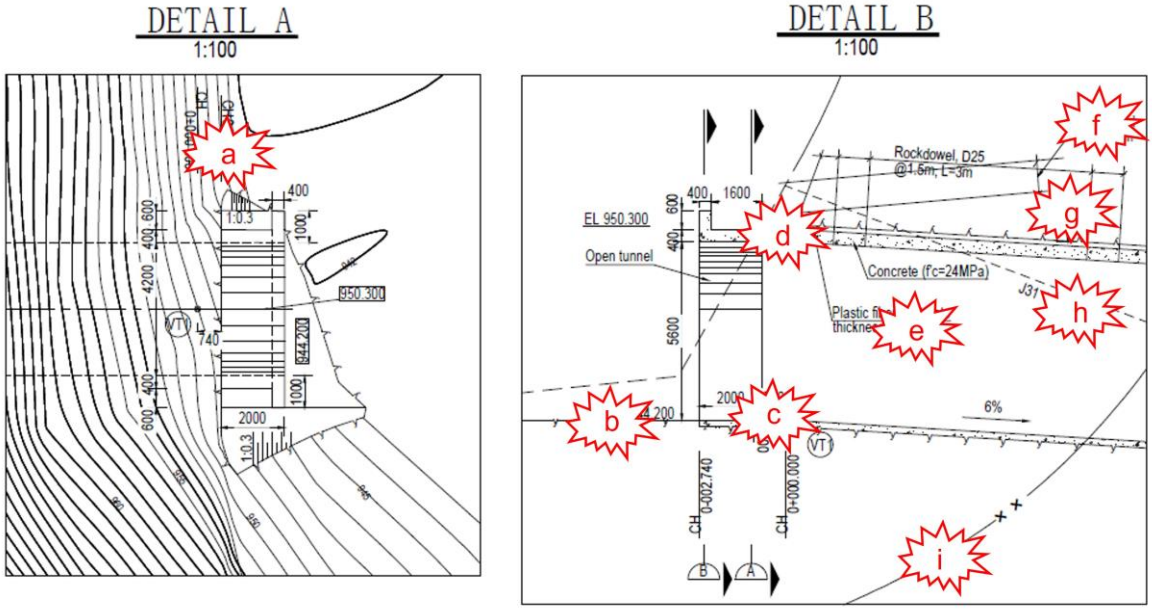
Photograph showing a typical saw-tooth profile in Class 1 rock of a tunnel in the Higher Himalaya.

Monitoring shall also be addressed on the drawings. Typical arrangements of sections with number of optical targets, distance between monitoring sections for each rock class, distance between tunnel face and installation of monitoring section, and type of target shall also be addressed.

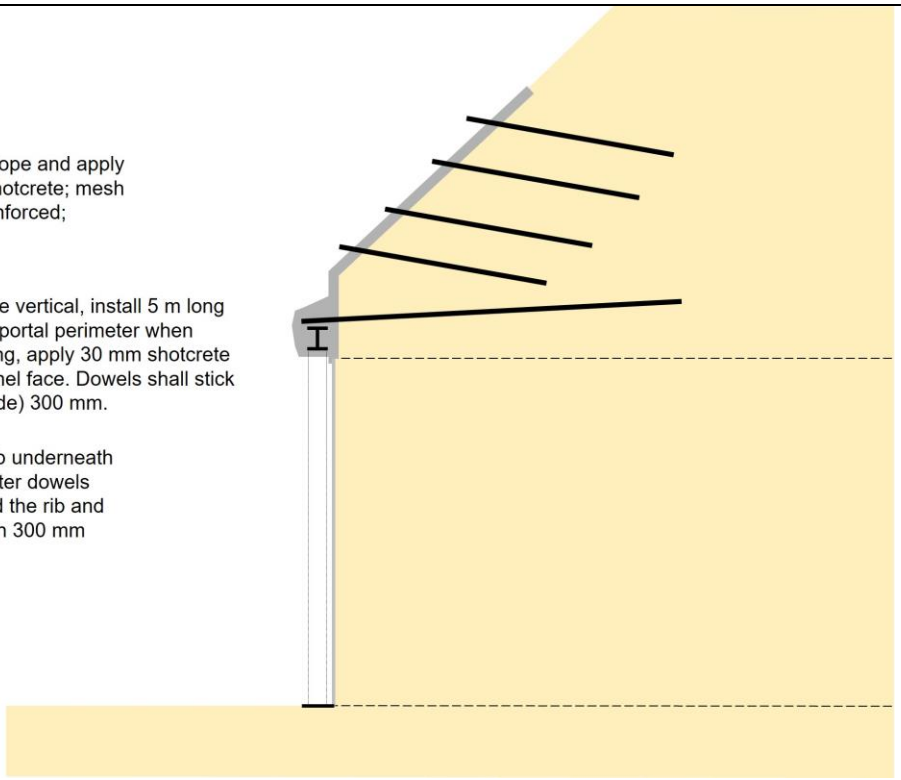
Drawing UT1-C-385-CVL-DG-65001, Rev. A

This drawing includes details of the portal structure including reinforcement and quantities of reinforcement. The reinforced concrete structure of the portal will be constructed at the end of the project. Until then, the requirements on this structure may have changed, e.g., it may require additional rock-fall protection or a particular gate. Therefore, it is currently not advisable to include reinforcement details of the structure constructed outside of the tunnel. The currently assumed thickness of 400 mm of the tunnel concrete lining at the portal was considered in the tunnel profile clearance, which is sufficient, but detail on the portal structure and its reinforcement are at the moment not required in this excavation drawing.

The sections of the tunnel shall show also the arrangement of the supply lines (fresh air, water, wastewater, electricity, compressed air) so that the clearance during construction is evident.



a) Chainage is given as 0-000.740, which is confusing. Generally, chainage is 0+000 where the tunnel enters rock. Consider and revise accordingly.
b) Indicate the assumed boundary soil/rock.
c) The tunnel is drawn horizontal at the portal and from Ch. 0+000.000 it slopes with 6%. This would require a kink in the reinforced concrete liner, which is very inconvenient when shuttering and reinforcing the concrete liner. In practice, it makes it also difficult to install the 5 m long spiles at the right angle. Generally, the tunnel should have one gradient in the portal section where the tunnel is concrete lined. Revise accordingly. The end of the portal concrete liner is not specified. The profile of the “Support Type of Tunnel Entrance Section” indicates, however, that it reaches to Ch. 0+007.000. Revise accordingly.
d) The rock where the spiles are installed need to be cut vertical. Consequently, the vertical portal cut slope get higher and the actual portal moves slightly inward. Steel support is generally required for the portal and for the first meters (steel ribs or lattice girder). The spiles shall stick out by 300 mm and a stell rib needs to be placed underneath the spiles. The sticking out spiles need to be fully embedded in fibre reinforced shotcrete (as shown in the sketch below).


1. Clean slope and apply 100 mm shotcrete; mesh or fibre reinforced; dowels.
2. Cut slope vertical, install 5 m long dowels on portal perimeter when slope cutting, apply 30 mm shotcrete skin at tunnel face. Dowels shall stick out (protrude) 300 mm.
3. Install rib underneath the perimeter dowels and embed the rib and dowels with 300 mm shotcrete.

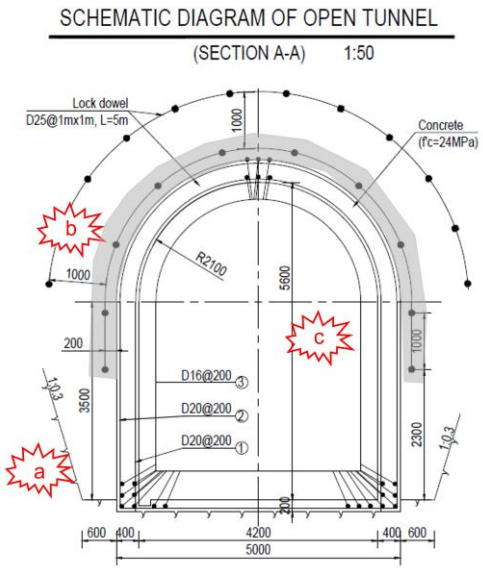
e) The thickness of shotcrete is around a portal generally > 100 mm. Only in Class I (or II) it may be 100 mm or even omitted (in massive rock, Class I).

f) A second row of spiles is not required (only in class IV or V it may be required). The second row is hence optional. Indicate this.

g) The “look-out angle” of the spiles shall be 4° at a maximum.

h) Use in all rock engineering documents (drawings/reports, excel-lists etc.) the notation of geological structures as follows: for planar structure use dip/dip direction (e.g., 46/330 or 70/065), and for linear structures use plunge/trend (e.g., 70/020 or 34/278). This is necessary as such noted data can directly be used by the engineer for calculations, e.g., wedge stability calculations for slopes or underground excavations.

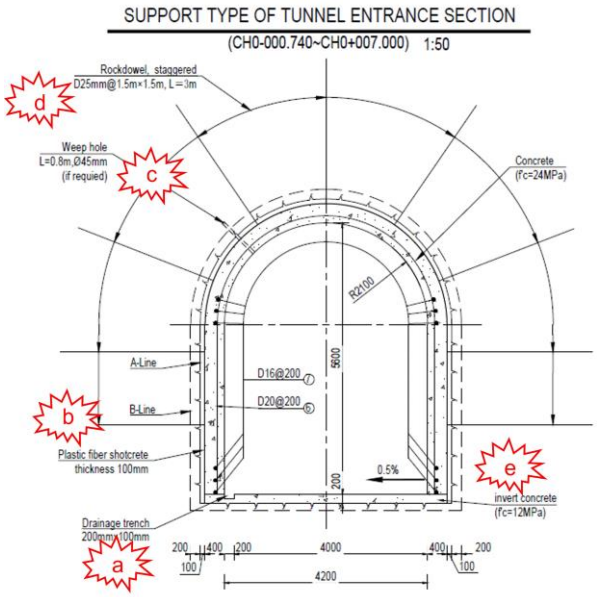
i) Omit this line of rock weathering grade as it is purely speculative.



a) The lateral space between the concrete liner and the rock slope of only 600 mm appears to be in practice too small. Revise.

b) Second row only indicative, 300 mm out of first row of spiles (= dowels), and staggered arrangement. Spacing of spiles shall be 400 mm as in the inner row.

c) Shadow the area that is reinforced concrete and indicate (similarly as in the figure left, where the area that is covered with 300 mm reinforced shotcrete is indicated).



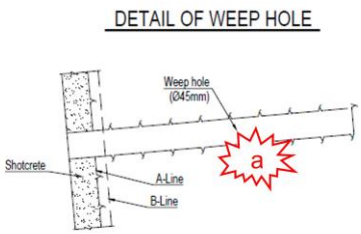
a) 100 mm of concrete below ditch is too thin. It requires excavating 100 mm more into rock.

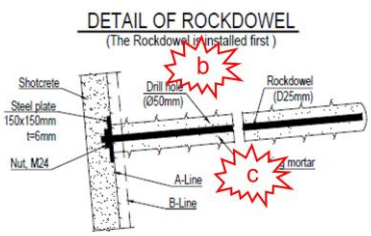
b) Indicate that thickness of fibre reinforced shotcrete depends on rock class.

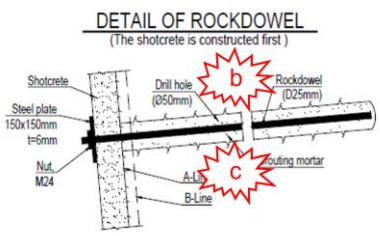
c) Weep holes in a reinforced tunnel liner at the portal are generally not required. However, contact and cavity grouting after concreting need to be indicated.

d) Indicate that spacing of dowels depend on rock class.

e) Invert concrete need to be (mesh) reinforced.



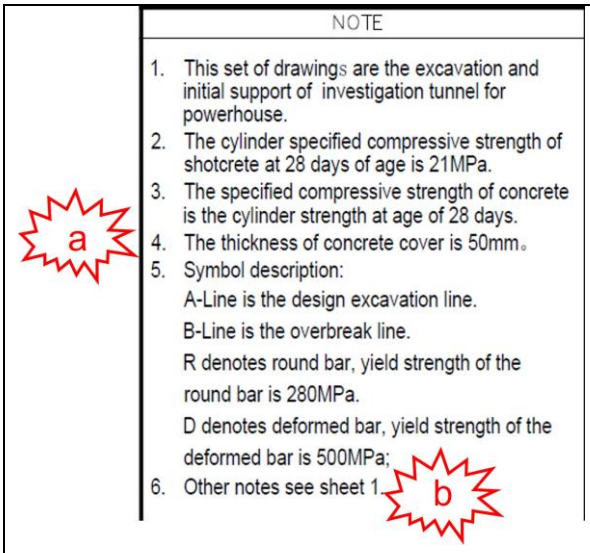




a) It shall be noted that weep holes require the insertion of a perforated PVC-pipe (wrapped with geotextile) for weathered rock (containing large number of fines).

b) Spacers, and their distance to each other, fixed on the steel bar shall be shown. They are necessary to keep the steel bar in the centre of the borehole to fully embed it in grout and consequently protect it from corrosion.

c) Generally, dowels are not installed using grout mortar (= sand + water + cement) as indicated, but with cement grout (= water + cement). The water/cement ratio (w/c) needs to be indicated in the drawing or the notes of the drawing. Experience shows that for dowels in slopes and in tunnel sidewalls, which are drilled at an angle of 10° downward, a water-cement ratio of 0.50-0.60 (max.) is the optimum as the grout flows into the borehole and fills it. In the tunnel roof, however, such w/c-ratio is far too high, and one will have always difficulty to fully embed the dowel in grout. A w/c-ratio of 0.30, i.e., a cement paste rather than a liquid needs to be used. Only with such low w/c-ratio dowels of reasonable bond strength can be installed.


NOTE
1. This set of drawings are the excavation and initial support of investigation tunnel for powerhouse.
2. The cylinder specified compressive strength of shotcrete at 28 days of age is 21MPa.
3. The specified compressive strength of concrete is the cylinder strength at age of 28 days.
4. The thickness of concrete cover is 50mm。
5. Symbol description:
A-Line is the design excavation line.
B-Line is the overbreak line.
R denotes round bar, yield strength of the round bar is 280MPa.
D denotes deformed bar, yield strength of the deformed bar is 500MPa;
6. Other notes see sheet 1.
a
b

a) The thickness of concrete cover of steel reinforcement shall be 50 mm.
b) See sheet 2 not sheet 1.

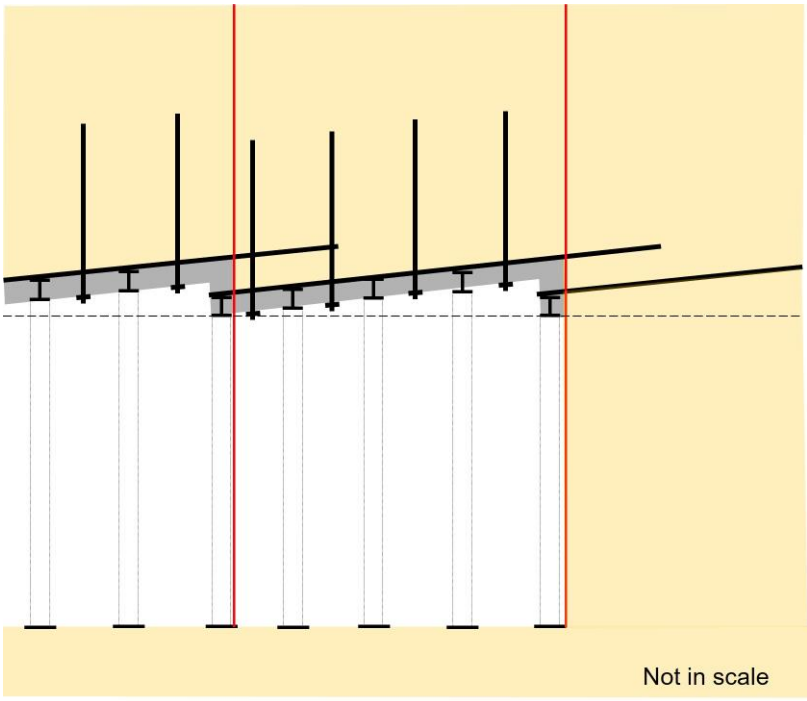
In addition to the Note, each drawing needs to specify reference drawings/documents. In this case it is at least the Layout Plan and the Method Statement of the Investigation Tunnel.

Drawing UT1-C-385-CVL-DG-65002, Rev. A

The drawings of the tunnel section for different rock/support classes are in general acceptable. Few issues such as indication of Q-value for each class and free unsupported span as discussed during the online conference of 31. August 2021 needs to be added. Furthermore, the dowels in the sidewalls of all profiles need to be inclined at 10° downward. Only above the springline, dowels shall be installed perpendicular to the tunnel perimeter.

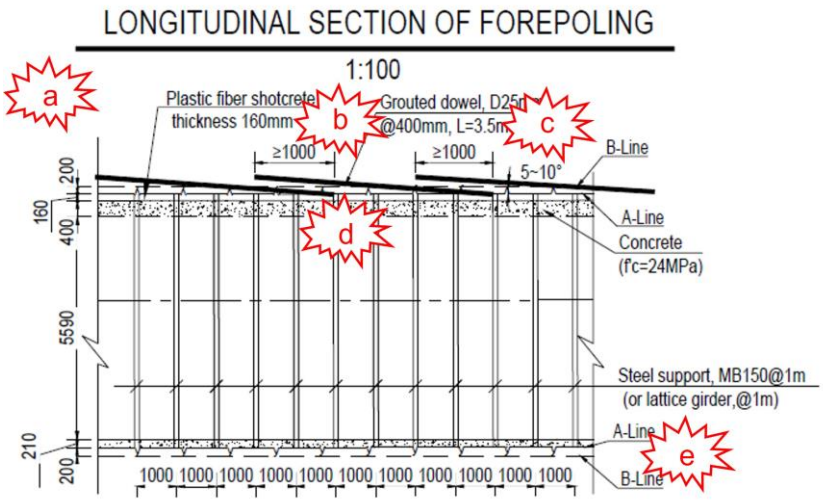
As this is not a water tunnel such as the Headrace Tunnel, it should be considered to replace the reinforced concrete liner for Class IV and V with fibre reinforced shotcrete. This may speed up the construction process. However, as the reinforced shotcrete has different strength than the reinforced concrete, the tunnel geometry needs to be changed due to different required thickness of shotcrete and concrete.

The longitudinal section of forepoling with spiles (= dowels) as shown on the drawing is practically not feasible to construct and it is statically not stable.

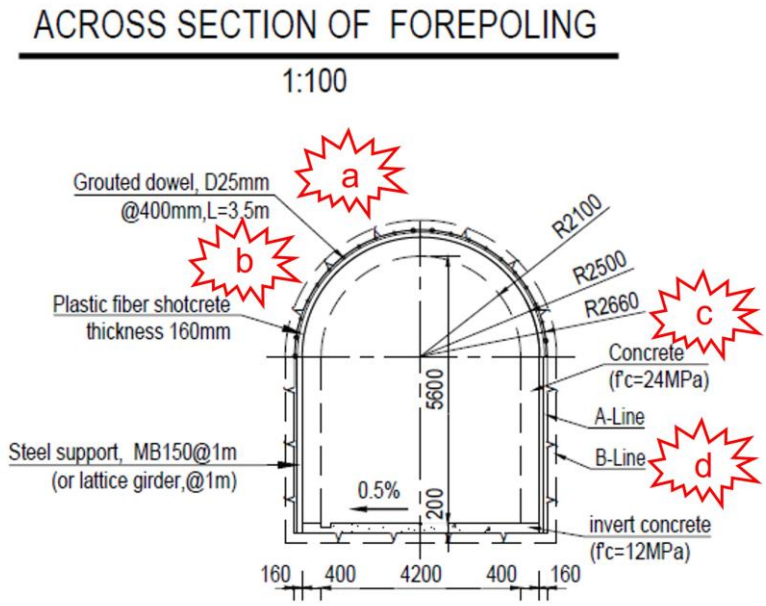


This sketch demonstrates schematically and in principle driving of a tunnel by fore-poling with spiles (dowels), which is practically feasible. The red lines indicate the location of the tunnel face, when new spiles (dowels) are installed. For tunnels smaller than 10 m in diameter the most economic and safe set-up is as follows: the length of spiles should be 6.0 m. The overlap of subsequent rows of spiles should be 1.7 m. The look-out angle of spiles should be 4°, only. 6.0 m long dowels still allow directional drilling to create a canopy. This length of spiles also allows reasonable distances between faces where spile installation is required. Note that installation of spiles is very time-consuming. In addition, this geometrical set-up allows to place under the newly installed spiles, which are sticking out (protruding) 300 mm, a supporting steel rib, which is then embedded in shotcrete. This is the same statical principle as applied at tunnel portals. Furthermore, this set-up allows grouting in-between the spiles (dowels).

It is noted that rib spacing shall be 1.0 m and the steel ribs are of different sizes. Dowels in the sidewalls and in the roof shall be at a spacing of 1.0 m c/c. This needs to be clarified during the design and the geometry of the individual ribs needs to be shown on the construction drawing.



a) Modify generally the drawing as suggested above or similar. Drive direction always from left to right.
b) Indicate rock dowels that are installed in the roof.
c) Indicate weep holes.
d) Clearly define out-look angle and overlap of spiles
e) Indicate longitudinal steel bar connections between ribs. Number the steel ribs as they have different size. (e.g. 1,2,3,4,1,2…)



Same/similar comments as above apply.

a) Add the profiles with the different geometry of the steel rib.
b) Indicate dowels in roof and sidewall and show staggered dowels.
c) Show weep holes with PVC-pipes and geotextile as Class V rock will always contain many fines.
d) Invert concrete needs to be (mesh) reinforced.

DISCLAIMER

Any approval will not release the Contractor from any of his obligations under the Contract.

Dr. Ulrich Glawe

(Signature)